Occupational Health Aspects Of Pesticides In Britain*

By

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FROM FISONS PEST CONTROL LTD.

THOSE OF YOU who still find time to read the medical and para-medical journals will have noted during the past ten years a steady flow of articles on the toxic hazards and public health problems of new chemicals for use in crop protection. Such articles vary between the informative, repetitive, discursive and frankly apprehensive. It is therefore a comparative pleasure to be able to consider these matters before a group of medical men who by their vocation already know that organized production, whether of fibres, fissionable materials or food, calls for the handling of materials, and that any material may cause harm if sufficiently mishandled.

There should perhaps be a special bond of understanding between medicine and agriculture, as in both professions one of the main problems is the conservation of the wanted species and the control of the biological enemies. In medicine, the enemies are those cells which, if unchecked, may cause wound sepsis, infectious diseases, malignant growths, or other disorders of structure or function. In farming, the pests are those fungi, weeds, insects, bacteria, viruses or vermin which threaten the crops. In both, the necessary treatment is based upon "good management" supported by selective chemotherapy. In farming, as in medicine, selective toxic action is sought by care in the choice of chemical for the problem, and then in the amount, time, place, frequency and method of application of the chemical treatment.

In attempting an assessment of the occupational risks of using these potent chemicals in crop protection, one must first consider the nature of the workers and the working conditions, and then the materials to be handled. In all these factors, variability is the rule, the exact circumstances of exposure being rarely duplicated between one man and another.

Manufacture and Formulation

The first group of exposed workers, numbering perhaps only a few hundreds in all, is the chemical operators and ancillaries of manufacturing and formulating factories. The occupational risks for these men are comparatively orthodox, basically similar to those encountered in other branches of the chemical industry and equally capable of control by suitable design, operation and supervision of processes. "Formulation" involves mixing the technical grade active chemical with solvents, wetting agents and other diluents or additives, and packaging it into suitable containers, from a few ounces to several gallons capacity. These are then labelled and sent off direct to farmers or to selling agents in agricultural and horticultural areas. The service is thus fairly direct, and the contents, the container and the instructions on use and safety must be suitable for direct action by the farmer or his employee.

Field Usage

The second exposed group of workers is the users themselves. In Britain alone, there are probably at least 30,000 persons who handle or use such chemicals in agriculture and horticulture. The area sprayed each year is over 3 million acres, or one-tenth of the total farmed land. The main users are farmers, farm workers, agricultural contract spray operators, orchard, glasshouse and hopyard workers, small-holders and sanitation, timber preservation and vermin-control teams. Scientific workers also handle the materials during research and development work. During application in the field, users work either alone or in teams of two or three. On a fine day in May, there may therefore be several thousand separate and isolated user-units handling the chemicals.

Methods of Use

The usual procedures in the field are to open the container, dilute the concentrated material, usually with water, and apply the diluted material evenly in a thin layer over a large area of crop or land. For this, application equipment is required, varying in complexity from a ladle and bucket to a fully-automatic delivery pipette, or from a domestic type "spray gun" to a large spraying machine holding 500 gallons of dilute wash to be applied in a 40 foot wide swathe at a speed of 4-6 m.p.h. Two men with massive equipment of this type can apply chemical to up to 200 acres of land each day. Spraying and

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dusting operations by fixed wing aircraft and helicopters are now an important occasional aid in special public health and agricultural operations, e.g. forests, tall crops and wide-scale infestations. Equipment is usually mobile, pressurized and rugged.

There is a wide variation in the conditions in which chemicals may be used, varying from open-field spraying to the fumigation of sealed buildings. Most application of chemical occurs in the open air on arable land, with the advantages of plenty of working space and natural ventilation, but the disadvantages of air-borne spray mist, and large acreages to treat. Orchards, hopyards and soft fruit acreages are more difficult to treat, involving overhead spraying, falling droplets, restricted unstable air movement and slow progress. Enclosed places such as glasshouses, grain stores and industrial premises are usually negligibly ventilated during spraying or fumigation.

Intensity of Exposure

The duration of individual exposure varies from a few hours per year for occasional users to several months of intensive use for contract spraying operators, timber preservation teams, ship fumigators, and other specialists. In general, most users have only a few days' exposure per annum, and the specialists who have prolonged exposure form only a small proportion of the total. Although work is almost independent of the weather during indoor operations, it is highly weather-dependent for outdoor operations. Most intensive use occurs during the warm or hot months of the growing season, and the heat waves and hot spells of April-August are usually very active times for crop protection, especially in the months of April, May and June. Cold weather, rain and strong winds usually halt all outdoor spraying operations. Thus, maximum exposure occurs when the climatic conditions, although pleasant enough for cricket or holidays, are often rather trying for the careful handling of chemicals for many hours a day, and the use of impervious protective garments is likely to be a source of great discomfort.

Probabilities of Contamination

During the course of chemical handling in the field, some personal contamination is inevitable, either of the exposed skin or the respiratory tract, or by accidental ingestion. Whether this will be dangerous or not depends mainly on the rate of absorption of chemical into the circulation and on its inherent toxicity.

If the chemical is cumulative in its toxic effects, as most agricultural chemicals are, then repeated minor over-exposures on successive days may eventually produce toxic effects. If the chemical is of very low acute toxicity, or non-cumulative in effects, the degree of contamination occurring may not be great enough to cause health risks.

The likelihood of personal contamination is influenced by a warning irritancy or the odour and colour of the material, but very much more by the personal habits and standards of the worker. Those who are inexperienced, untrained, careless or in a hurry, or who believe too certainly in their personal immunity to chemicals of all types are more likely to become occupational casualties, in farming as in factories.

Because of the variability in the nature of the work and workers, it is difficult to be certain which is the most important route of entry of chemical into the body. The use of volatile fumigants, aerosol dispensers, finely atomized sprays, fine dusts and smoke generators in enclosed or ill-ventilated premises could undoubtedly cause inhalational risks. Volatile fumigants such as HCN and methyl bromide quickly cause dangerous vapour concentrations, but the remainder cause mainly particulate risks. The only important exception is the use of the more volatile alkyl mercurial compounds in enclosed spaces, where vapour concentrations may build up to dangerous levels if ventilation is poor. Where fine particles settle, there is then a risk of contamination of hands, clothing and food by small amounts of the chemical.

Oral ingestion of small amounts of chemical probably occurs under some conditions of use, from such factors as contamination of eating, drinking or smoking materials, or from blowing or sucking dirt from blocked jets by mouth. This route of absorption of chemical is probably only of minor or occasional significance, however.

Skin Contamination

The vast majority of chemical applications occur outdoors; no significantly volatile chemicals could be used economically under such conditions. Observations during outdoor spraying in North America and this country have all shown that the inhalational hazards in such work are small by comparison with those from contamination of the exposed skin. Skin contamination may occur when handling the concentrated chemical during opening and filling-up, from repeated contamination of the hands by the dilute material, or by brushing against contaminated surfaces. Toxicological studies show that fatal poisoning of animals is possible by skin absorption of the more poisonous chemicals, but those of lower toxicity cannot readily be applied to the skin in sufficient single amount to cause death. The solvents and wetting agents added to formulations may in some instances increase the rate of penetration of the skin, and make decontamination of the area less effective.

There is little doubt of the practical importance of skin contamination as the major occupational hazard during field application. The toxic herbicide dinitrocresol (DNC) is a bright yellow dyestuff, and skin contamination shows up as a persistent yellow stain. A laboratory method exists for determining blood levels of DNC, and the relation of blood DNC to risks of poisoning is established. During the performance of many

Table I

ASSESSMENT OF POTENTIAL HAZARDS OF AGRICULTURAL PESTICIDES

Group	Order of risk	Chemicals
Fumigants	Slight	paradichlorobenzene, naphthalene, ethylene dichloride
	Intermediate	ethylene dibromide, carbon tetrachloride, chloropicrin, azobenzene, dichloropropane, *formaldehyde
	Considerable	*HCN, methyl bromide
Fungicides, viricides	Slight	*copper compounds, *dithiocarbamates (Zn, Mn, Fe), captan, *sulphur, *lime-sulphur, tetramethylthiuram-disulphide (TMTD), antibiotics (streptomycin, griseofulvin)
	Intermediate	*organomercurials (1–2%, as used in seed-dressings)
	Considerable	organomercurials, organotin compounds
Herbicides	Slight	*sodium chlorate, borates, kerosene, sodium *trichloracetate and monochloracetate, maleic hydrazide, monuron (CMU), dalapon, "*growth hormone*" *type weedkillers*: *2,4-D, *MCPB, 2,4,5-T, *MCPA, 2,4-DB
	Intermediate	pentachlorphenol
	Considerable	arsenites, sulphuric acid, *dinitro-o-cresol (DNC), *dinitro-butylphenol (DNBP, dinoseb)
Insecticides	Slight	*DDT, *benzene hexachloride* (BHC), *tar oil fractions, pyrethrum, derris, mineral oils, methoxychlor,* toxaphene, *organophosphorus compounds*: *malathion, chlorthion, dipterex and diazinon
	Intermediate	heptachlor, *dieldrin, *aldrin, lead arsenate, chlordane, *organophosphorus compound*: *methyl demeton
	Considerable	nicotine, endrin, organoselenium compounds, *organophosphorus compounds*: *parathion, amiton, *TEPP, HETP, demeton, thimet, dimefox, *schradan, sulfotepp
Rodenticides	Slight	*warfarin, pival, red squills
	Intermediate	*α-naphthyl thiourea (ANTU)
	Considerable	fluoracetates, fluoracetamides, yellow phosphorus, *zinc phosphide, strychnine, HCN, barium fluoride, *arsenious oxide

**indicates chemicals of the group which are most extensively used in British practice*

hundreds of such tests, the relation between the yellowness of the hands and the blood DNC level has been striking and consistent, both in factory workers and in spray operators. In one stores-hand, failure to thoroughly decontaminate the skin of the back after splashing of the clothing and neck by concentrated DNC caused a rise of blood DNC from 6 μg/ml to 30 μg/ml during the next twenty-four hours, with minor toxic effects. When 1 gm of DNC, as a slurry, was kept in contact with a human subject's hand for eight hours, inside a rubber glove, the blood DNC level rose to 15 μg/ml within twenty-four hours. Some campaigns with toxic materials have been carried out in safety by adopting regular, frequent and thorough hand washing as the sole safety precaution against toxic risks. Reliable information on spraying hazards is still sketchy, however, and the number of careful investigations so far made on risks in the field is very small indeed by comparison with the thoroughness of occupational hygiene surveys in factories.

The Comparative Toxicity of Agricultural Chemicals

Just as the workers and working conditions show much variation, the chemicals themselves vary greatly in their toxicity and important properties. Hundreds of useful chemicals exist, but there is a hard core of very important materials, about a score in number, which are most extensively used in this country. Manufacturers adopt a high standard of care when putting new chemicals on the market, and all new chemicals undergo toxicological investigations before marketing occurs. The data from such experiments cannot easily be extrapolated to man, however, and from time to time, the different sensitivity of man, or the circumstances of work, cause troubles which could not have been prophesied from theory. In other cases, materials of high toxicity to animals prove safely usable under the conditions for which they are required in crop protection.

Table I does not attempt to give detailed quantitative data on the "toxicity" of the chemicals, but is simply an assessment of probable or established user-hazards, based upon the laboratory and field data which exist upon the properties, hazards, and medical histories of the chemicals. As a general indication, however, the materials presenting "slight" hazards have very low or low toxicity to animals (acute oral LD 50 values varying between 200 and 10,000 mg/kg); those presenting "considerable" hazard have high or very high toxicity (LD 50's of 0·5 mg/kg to perhaps 50 mg/kg) and those of "intermediate" hazard are of intermediate toxicity. Much over-

lapping of laboratory LD 50 estimates occurs between the three groups, and in general, the problem of assessing risks in actual use causes the same difficulties with agricultural chemicals as with industrial materials. In *Table I*, the asterisked chemicals are those which are most used in this country.

Occupational Mortality in Britain

The preceding paragraphs have dealt at some length with the potentialities of the situation. It now remains to deal with the findings in recent practice.

During the past eleven years, a period of great technical advances and increase in the use and availability of chemicals, there have been eleven fatal cases of poisoning among users of the chemicals in British agriculture. Of these, eight deaths occurred during 1946-1951 due to the use of the toxic herbicide DNC, one in 1955 from the use of sodium arsenite to kill potato haulms on a Jersey small holding (*Evening Post*, Jersey, C.I. 16th August, 1955), one in 1954 from parathion used in glass houses in Guernsey (*Evening Post*, Jersey, C.I. 24th July, 1954), and one in 1955 as a delayed effect attributed to use of a volatile organomercurial fungicide (ethyl mercuric phosphate) in an Essex glasshouse (*Cambridge Daily News*, 3rd December, 1955).

The deaths from DNC during its earlier years of use were almost certainly caused by repeated severe skin contamination, the absorbed chemical being potentiated in its toxic effects by the heat waves and hot weather occurring at the time. All eight men concerned were intensively exposed to the chemical, as contract spraying operators, and had carried out some days or weeks of spraying. The early warning signs of intoxication had usually been ignored, and exposure continued (Bidstrup and Payne, 1951).

The other three deaths had some elements of mystery, in that exact method of fatal overexposure could not be determined in any of them.

Occupational Illnesses

No reliable data exist on occupational morbidity or minor toxic effects among users. Transient indispositions from occupational over-exposures probably do occur each year, but as these cases would tend to show somewhat vague symptoms, and would be encountered mainly by practitioners in rural areas, very few cases have been authenticated and reported. The reverse also applies, however, in that each year quite a large number of cases of possible "spray-chemical" poisoning are reported to manufacturers' medical advisers, almost invariably giving negative laboratory tests when investigated. The lack of evidence of an appreciable morbidity rate may be explained by failure to look for and find such cases, but most of the more hazardous chemicals used are acute poisons, with no tendency to cause prolonged mild illnesses or chronic effects after single episodes. Exceptions to that statement include elemental materials, such as mercury, arsenic and lead, where complete detoxication and excretion occur less readily than with complex organic molecules possessing side-groups lending themselves to attack by detoxication chemistry. A further exception exists in the organophosphorus insecticide, mipafox, which in 1951 was the cause of accidental acute anticholinesterase poisoning in three development chemists operating a pilot plant (Bidstrup, Bonnell and Beckett, 1953). This compound was of special interest because it was later shown to be markedly more toxic to higher mammals than to rodents, and had a near-unique property in an ability to demyelinate nerve fibres and thus cause delayed limb paralysis as a secondary mode of action, probably unrelated to its anticholinesterase toxicity. This compound, although a good insecticide, was not further developed.

Public Health

There has been a negligible number of cases of suicide, homicide or accidental poisoning from the misuse of pesticides in Britain, and, despite the anxieties expressed from time to time, the use of new chemicals in increasing amounts has thus far caused no instances of illness due to chemical residues on food crops. There is no logical or justifiable suspicion that any injury to the public health has been or may be caused by the use of these chemotherapeutic materials in farming, as long as the present type of care is taken to ensure correct use.

Bases of Safety

Thus the present situation, covering the past eleven years in Britain, is that there have been eleven fatal cases of occupational poisoning, a very small number of non-fatal cases, and no adverse effect of these chemicals on public health. One might then logically ask, where lie the risks? First, other countries in which the same chemicals have been used under less well disciplined and more adverse conditions have had far greater numbers of occupational casualties. Secondly, there is no doubt whatever about the toxic potentialities of some of the chemicals, or that the present standards of safety in Britain have come from the cautious and attentive approach of impartial authorities to the increasing use of these chemicals. For the past ten years, liaison has steadily been increasing between manufacturers, users and official advisers, and control measures have been carefully devised at early stages of the problems. In this country we have few problems from language, literacy, climatic extremes, availability of advice or protective measures, and we have a very effective system for alerting users through their trade journals and the press. Other countries have not all these advantages, so misuse and over-exposure are far more likely to occur. Thirdly, agricultural tradition in Britain emphasises good husbandry, and our climate does not induce the vast numbers of

voracious pests such as occur in the tropics and subtropics. Thus, the scale of use of toxic insecticides in Britain is still much less than in some intensive growing areas in America, Africa and tropical countries. Finally, most use is made of materials of low toxicity, presenting negligible hazards to the user.

Risks to Farm Stock and Wild Life

There are, however, certain adverse side-effects which seem almost inseparable from the use of active biocidal chemicals in agriculture. Human negligence, accidents and the inquisitive habits of farm stock produce a number of casualties each year among domestic animals, mainly due to the consumption of vegetation on or near areas recently sprayed with the more toxic compounds, especially some organophosphorus insecticides, and arsenicals. Similarly, wild birds and gamebirds fall occasional victims to the more toxic chemicals, when they seek food, water or shelter on recently sprayed areas. Again, some chemicals tend to cause casualties among beneficial insects and pollinators. Such incidents cause some litigation, and much indignation from owners, and cause a number of anxious questions to be asked of our legislators. Manufacturers are more than sympathetic about these incidents, but so far have no more attained the pipe dream of absolute selectivity than has the pharmaceutical industry for our medical needs.

Statutory and Voluntary Protective Measures

The safe use of agricultural chemicals in Britain is sought by statutory measures, voluntary agreements between manufacturers and official departments, and further voluntary actions by individual manufacturers and users.

By recent agreement, proposals to market new chemicals or new radically changed formulations, or to use known products on further food crops are voluntarily notified to the Ministry of Agriculture, Fisheries and Food, with detailed information on the toxicological or analytical aspects of the proposal. The proposal is considered by an Advisory Committee on which several government departments are represented, as well as other advisory groups such as the M.R.C. and Nature Conservancy. This Committee's view is passed formally to the Ministries and Departments concerned. The firm concerned is then notified of the official views and recommendations on the safety of users and the public, and naturally accepts those recommendations as advice which may not be ignored.

If the new product appears to be of a high order of risk in use, it may be added to the Poisons Rules, which limit the circumstances in which it may be sold to the public. It may also be made a "Scheduled Substance" under the Agriculture (Poisonous Substances) Act, 1952, with which authority the Minister of Agriculture can frame regulations which specify what safety precautions shall be taken in its use, by both employer and employee. At the present time, the Scheduled Substances include the dinitro-weedkillers, the more toxic organophosphorus insecticides, arsenites and organomercurial compounds when used as aerosols. Protective requirements may include the provision, safe custody, washing and wearing of protective clothing, the list of variants including rubber boots, gloves, apron, coat, sou'wester, white cotton overall with or without hood, faceshield, dustmask, charcoal-canister respirator, mackintosh. The employer must also provide clean drinking water and utensils, buckets for personal washing, containers for food and facilities for washing equipment clean of contamination. He must also keep a register of the hours of spraying with scheduled substances, records of sickness absence due to spraying, and results of specific blood analyses for over-exposure. Use of scheduled substances is restricted to 10 hours daily, and 60 hours per week, and to workers over 18 years of age. The Regulations are enforced by Area and County Inspectors of the Ministry, and prosecutions have occurred. Although there is probably a tendency towards over-protection in some details, the general effect of the Regulations has been to the advantage of users, and thus of the industry, in long term view.

The safety of foodstuffs to be eaten by the public is safeguarded by the adoption of the Committee's recommendations on the interval which should elapse between spraying and harvesting food crops. Although these views are not enforced by law, other than through the Food and Drugs Act, all manufacturers and the major growers pay much heed to the necessity of ensuring clean and uncontaminated food. The safety interval is not guessed, but derived from the results of chemical analyses on treated crops and the results of prolonged dietary toxicity tests on animals, which accompany the manufacturer's notification to the Committee. In other countries, whose problems are probably different, a more rigid system of maximal permissible levels of food contamination is enforced, lists of "residue tolerances" being determined, publicised, and to some extent enforced.

The labels of chemical containers bear any warnings required for poisonous materials, and the safety precautions recommended by agreement between official departments and the manufacturer or the industry. For poisonous compounds, first aid, diagnostic and medical information is briefly given, and a warning colour may be added to the chemical. Many spraying contractors have gone to considerable lengths in devising and adopting extra safety precautions, such as fully enclosed cabs for the tractor driver, with forced ventilation by air passed through particulate filter material and active charcoal. Large machines may have lightweight covers over the spraybooms, to reduce the spread of airborne spray mist to susceptible crops and adjacent grazing pastures. Many spraying contractors now arrange for the periodic health inspection of their

operatives during periods of intensive use of the chemicals, and make use of two invaluable laboratory diagnostic measures which determine the standard of safety attained during the work. In the first test, a 1 ml sample of blood is analysed for dinitrocresol, using a colorimetric method. In the second test, the earliest symptomless effects of organophosphorus insecticides are detected by determining the normality of cholinesterase enzyme activity in the blood; all the organophosphorus insecticides are inhibitors of cholinesterase, and from 50 to 80 per cent depression may occur before toxic effects become evident; such depression is dangerous in that it produces extra susceptibility in the workman. Both the above specific tests can now be carried out in a few minutes in the field, using portable equipment (Edson, 1954; Edson and Fenwick, 1955).

The statutory and voluntary measures described above have arisen mainly from the enquiries and recommendations of three successive official Working Parties headed by Sir Solly Zuckerman, first on user-risks (H.M.S.O., 1951), then risks to the public health (H.M.S.O. 1953) and finally risks to wild life (H.M.S.O. 1955). The problem of safe use of pesticides exists in most temperate and tropical countries, for agriculture, food storage and public health. To provide a central fund of knowledge and expertise, the World Health Organization has set up a Study Group on Pesticides, whose two surveys of the toxic hazards of these chemicals (W.H.O. Monograph No. 16, 1953: W.H.O. Technical Report No. 114, 1956), are an important and impartial contribution to progress.

There has gradually arisen in Britain a tradition that new industries presenting possible or obvious potential risks may confidently be started up without fear of catastrophe or severe consequences to occupational or public health, provided that management and medical advisers are alert, attentive and co-operative from the outset. The expansion of use of new synthetic chemicals in agriculture and public health in Britain, although presenting some problems which do not normally arise in industrial activities, appears so far to have kept well within that tradition.

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DISCUSSION

DR. G. F. KEATINGE (*The Butterley Co. Ltd.*): Would Dr. Martin please enlarge on the imbalance of nature brought about by the use of insecticides and weed-killers?

DR. MARTIN: The important thing is that this imbalance has been recognised. A lot of work has been done in the last few years, particularly at the East Malling and Long Ashton Research Stations. The trend will be towards the development of chemicals which are more specific in action. It is recognised that with some chemicals there is a risk that the natural balance will be upset too much.

DR. KEATINGE: What precautions are taken for control in the use of these pesticides? Of the 30,000 possibly exposed to occasional risk, how many are employed by large contracting firms? The majority of small farms employ less than two permanent workers; what regulations are observed under these conditions?

DR. EDSON: Although precise figures are not available, it is probable that there are 1,000-2,000 employees of agricultural contractors, engaged full-time on spraying during the spring and early summer months. The vast majority of users have very limited personal exposures, and this is probably a very significant safety factor. The Statutory Regulations, which prescribe certain measures of care, apply to all employers and all employees using the scheduled poisons in agriculture, but not to the self-employed private user, who usually handles such materials for a very short time annually and who is advised by the manufacturers' safety recommendations issued with each container.

DR. KEATINGE: Professor Grunsell has not mentioned foot and mouth disease—I should be glad to hear something of this interesting subject as humans are affected at times.

PROFESSOR GRUNSELL: One source of infection to man is infected milk, and there have been some cases reported in children; but I think I am right in saying that from a public health point of view the effect of foot and mouth disease on humans is not thought to be very important.

DR. R. E. W. FISHER (*S.E. Gas Board*): I am pleased to hear from Dr. Edson that the danger from parathion and other pesticides is not as great